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(54) SYSTEM FOR THE CONTROL OF FLOW OF VENTILATING AIR

(71) We, THE GARRETT CORPORATION, a Corporation organised under the laws of the State of California, United States of America, of 9851—9951 Sepulveda Boulevard, P.O. Box. 92248, Los Angeles, California 90009, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to fluid flow control methods, apparatus and systems, and is more particularly concerned with methods, apparatus and systems for controlling the ventilating air flow from a source thereof through a duct to an aircraft cabin or the like, in accordance with a desired temperature of the air in the cabin. The preferred forms of apparatus and systems embodying the invention are actuated completely by relatively low pressure control fluid supplied by a control fluid source which may be pneumatic.

Gas turbine-powered aircraft can utilise pneumatic pressure from the engine to air-condition the aircraft. Control of the temperature of the conditioned air to provide the optimum in passenger comfort can be accomplished by various methods. The most common currently in use senses the air temperature electronically, and uses electrical or electropneumatic controls to mix hot and cold air to obtain the desired temperature.

The conversion interfaces between components of differing types, that is between electronic and electrical or electropneumatic, provide sources of possible trouble and lower reliability. Furthermore there may be maintenance problems down the line, e.g., periodic lubrication of components for one.

Additionally, the pneumatic supply lines usually associated with electropneumatic components have been metallic tubing with flared end fittings in order to handle the fluid pressures involved. These are troublesome sources of continuing inspection and maintenance requirements by reason of vibration problems encountered. In addition, the original installations are relatively expensive since the tubing has to be curved, and bent and fitted carefully to the particular installation.

According to one aspect of the present invention, apparatus for producing at a signal output port a fluid pressure output signal which is dependent on a fluid pressure input signal and on a sensed temperature comprises a metering valve, pressure responsive means arranged to exert on a movable valve member of the metering valve a force dependent on the fluid pressure input signal, but substantially independent of the fluid pressure output signal, temperature responsive means arranged to sense a fluid temperature and to exert on a movable valve member of the metering valve a force dependent on the sensed temperature, and fluid pressure supplying means supplying a restricted flow of fluid to the output port whence the metering valve bleeds fluid to vary the output signal. The output signal can be taken from the junction of the fluid pressure supplying means and the metering valve, whereby the output signal varies with variations in the pressure drop across the metering valve.

According to another aspect of the invention, a system for controlling the flow of ventilating air to a compartment comprises a supply duct having a flow control valve, and apparatus according to the first aspect, the temperature responsive means of the apparatus being positioned to sense the temperature of the ventilating air downstream of the flow control valve, and the system also including a fluid pressure responsive actuator connected to receive the fluid pressure output signal from the apparatus and to position the flow control valve in accordance with the

output signal, and setting means arranged to provide a steady fluid pressure input signal to the apparatus.

Accordingly, the invention aims to provide apparatus and systems for the control of the flow of a working fluid in which the control apparatus is substantially, if not totally, fluid in its operational requirements with little or no electronic or electrical sources or interfaces, or electropneumatic or conversion elements required. The invention has features which make it advantageous for use in the control of the ventilating air supplied to the cabin of an aircraft, such as lightweight, long life, low cost components having a minimum of moving parts for high reliability and negligible maintenance since no periodic lubrication is required. To achieve low weight, the component housings may be fabricated by the technique of injection moulding of high strength non-metallic materials having one-half the weight of aluminium. Illustrative of available materials for the purpose is a fibreglass reinforced thermoplastic polyester (polybutylene terephthalate) known as Valox 420–SEO which exhibits good tensile strength up to a temperature of 177°C (350°F). Additionally, the material is self-extinguishing; that is, it will not support combustion.

Long life is characteristically of the order of a 30,000 hour overall life with a minimum of 4,000 hours MTBF (mean time before failure). Low cost is achieved by an optimum commonality of parts, whereby the maximum benefit is realised for large quantity fabrication by injection moulding tooling having unusually long life with substantially no need for replacement due to wear.

It is found with embodiments of the invention that the consumption of fluid for the operational requirements is very low. In a typical case the pressure requirement is about 30 psi and the consumption may be of the order of approximately 0.1 pounds per minute maximum of supply air. It is found possible to provide a system of great simplicity which may comprise three primary components in one case, or a maximum of four in another case.

The invention may apply to a system which may be employed in aircraft having either pressurised or unpressurised cabins, and is adaptable to any source of hot and cold air which may be available in a particular case. For example, in the case of unpressurised cabins the cold air source may be that of ambient atmosphere and the source of hot air may be a bleed from the compressor section of the aircraft's turbopower or jet engine. In the case of pressurised cabins the cold air source may be the air conditioning unit on board.

A system according to the invention provides the important advantage of a fast, positive system response, for example, a 30 second maximum response time to a command for a 10°F change, while maintaining a selected temperature to within plus or minus 1°F steady state. Noteworthy is that the maximum temperature overshoot and undershoot of the system from a 10°F change command is typically of the order of 2°—4°F.

The invention may provide a system with over-temperature protection of all aircraft components and ducting downstream of the hot air mixing section in the case of a system controlling an add-heat valve means controlling the hot bleed air mixed with the cold air for ventilating purposes. Furthermore, means may be provided for a manual override mode of operation, whereby the operator has direct control of the add-heat valve by means of the temperature selector means, and the system may have a fail-safe "cold" in the case of, for example, a leak in the control pressure line coupling the components.

The invention may be carried into practice in various ways, but several specific embodiments will now be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic illustration of a basic system embodying the invention;

FIGURE 2 is a schematic illustration of a typical system embodying the invention, complete for application to an aircraft having a pressurised cabin;

FIGURE 3 is a schematic illustration of another typical system embodying the invention, as applied to an aircraft having an unpressurised cabin;

FIGURE 4 is a schematic illustration in cross-section of a temperature selector employed in the systems of Figures 1, 2 and 3;

FIGURE 5 is a schematic illustration in cross-section of a controller employed in the systems of Figures 1, 2 and 3;

FIGURE 6 is a schematic illustration in cross-section of a bleed-on pressure regulator employed in the systems of Figures 2 and 3;

FIGURE 7 is a schematic illustration in cross-section of a temperature limiter employed in the systems of Figures 2 and 3;

FIGURE 8 is a schematic illustration in cross-section of a mode selector employed in the systems of Figures 2 and 3;

FIGURE 9 is a plot of performance curves of one embodiment of the invention, to illustrate response to a temperature-rise command;

FIGURE 10 is a plot of performance curves of that embodiment of the invention to illustrate its response to a temperature-drop command; and

FIGURE 11 is a plot of a performance curve to illustrate the operation of the temperature limiter component.

Figure 1 shows a compartment 10, which may be an aircraft cabin, for example,

supplied by a working fluid, which may be ventilating air, through a supply duct 12 whose upstream end is connected to hot and cold fluid sources by a hot air duct 14 and a cold air duct 16, respectively. The flow of hot air is controlled by a flow control valve 18 shown as an add-heat butterfly valve arranged for actuation by a valve controller 20 including a housing 22 defining a chamber 24 having a pressure responsive movable wall 26, with one face subject to the pressure in the chamber 24 and being coupled by a rod and lever 28 to the butterfly valve 18 to position the valve as a function of the pressure in the chamber 24. As pressure in the chamber 24 increases, the valve 18 is moved in an opening direction to permit increased hot air flow through the duct 14 to the duct 12 and thence to the compartment 10. A spring 29 serves to urge the movable wall 26 in a direction to close the butterfly valve 18.

Control of the pressure in the chamber 24 is accomplished by a control system which comprises a temperature selector 32, a first controller 24, and a second controller 36.

The selector 32 is of the bleed-off variety and is best seen in Figure 4 as having a housing 38 within which is threadably disposed a variable-position spring retainer 40 having an operator stem 42 extending therefrom and provided with an operator handle 44 on the upper end thereof for manual rotation of the spring retainer 40 in the housing 38. The operator handle 44 is provided with an indicator 46 having a pointer (not shown) disposed over an indicator scale (not shown) to indicate the temperature selected, as depicted schematically by the arcuate line 48. The housing 38 is provided with bleed control means 50 comprising a poppet valve 52 co-operating with a valve seat 54 formed in a passageway 56 defined by the housing 38 and providing communication between ports 58 and 60. The poppet valve 52 is urged into engagement with the seat 54 by a spring 62 having one end engaging the poppet 52 and the other end disposed in a recess in the bottom end of the spring retainer 40. Thus, fluid pressure on the face of the poppet valve 52 tends to lift the valve, opposed by the adjustable force of the spring 62, and to bleed the fluid from the port 58 to the port 60 which may be vented to a sink source of fluid at a lower pressure. In effect, the temperature selector 32 is an adjustable or variable pressure regulator to maintain an adjustable or variable regulated fluid pressure at the port 58. In this embodiment, the pressure at the port 58 is adjusted upwardly when the operator handle 44 is moved for a selected temperature increase in the compartment 10, and vice versa.

The first and second controllers 34 and 36 are identical in structure. As seen in Figure 5, they each comprise a housing 64 defining a chamber 66 having a pressure responsive means 68 shown here as a movable wall which includes a rigid disc 70 provided with a peripherally disposed flexible diaphragm 72 whose peripheral edge is secured to the housing 64 in any preferred manner, and with one face subject to the pressure in the chamber 66. A calibrating compression spring 74 is disposed between the disc 70 and an adjusting disc 76 which is arranged for adjusting the bias force of the spring 74 on the disc 70 by means of an adjustment screw 78 which is threadably received in the housing 64.

The housing 64, together with the lower faces of the disc 70 and the diaphragm 72, defines a passageway 80 communicating between ports 82 and 84. The port 84 will be referred to hereinafter as a signal output port. Disposed in the passageway 80 between the ports 82 and 84 is a metering valve 86 comprised of first and second valve elements 88 and 90. The first element 88 is a portion of the underside of the disc 70 which engages the end of a nozzle which constitutes the second element 90 communicating with the signal output port 84.

The housing 64 has secured to it a temperature sensor 92 forming a co-operative part of the controller, and comprising a cage-like housing 94 within which is disposed an actuator rod 96 whose upper end is arranged for engaging the underside of the disc 70. The lower end of the rod 96 is secured to the upper end of a bellows 98 whose lower end is secured and sealed to an inner face of the housing 94. The cage-like configuration of the housing 94 permits free flow of the working fluid in contact with the bellows. With this arrangement, expansion of the bellows 98 causes the rod 96 to lift the disc 70 and thereby the first valve element 88 from the second valve element 90. Further movement of the rod by additional expansion of the bellows causes the valve element to meter the fluid flow in the passageway 80 between the ports 82 and 84 as a function of the temperature of the fluid sensed by the temperature sensor 92.

To obtain the bellows action as aforesaid, the bellows is filled with a fluid which provides a large variation in vapour pressure with temperature changes of the working fluid to which the bellows is subjected. To this end it is preferred to fill the bellows with one of the halogenated hydrocarbons which provide this characteristic, such as one of the Freon-type fluids whereby the positioning movement force of the bellows is a predictable function of the temperature.

In the embodiment shown on Figure 1, the temperature sensor of the first controller 34 is disposed to sense the temperature of the air

in the compartment 10, and the temperature sensor of the second controller 36 is disposed to sense the temperature of the air in the duct 12 upstream of its exhaust into the compartment 10.

The housing 64 has a signal input port 100 communicating with the chamber 66. In Figure 1, the port 58 of the temperature selector 32 is coupled to the signal input port 100 of the first controller 34 by a conduit 102 and the signal output port 84 of the first controller is coupled to the signal input port 100 of the second controller 36 by a conduit 104. The signal output port 84 of the second controller 36 is coupled to the chamber 24 of the valve controller 20, by a conduit 106. Pressurised control fluid from a source (not shown) is supplied through a supply conduit 108 having first, second and third fluid supply conduits 110, 112 and 114 respectively, coupled through orifices 116, 118 and 120, to the conduits 102, 104 and 106, respectively.

The basic system of Figure 1 is incorporated in the system illustrated schematically in Figure 2, including a temperature selector 32 and the controllers 34 and 36 coupled in cascade by the coupling conduits 102 and 104. Also, the system is supplied from a supply conduit 108 which is coupled to a pressurised controlled fluid source through a conventional fluid pressure regulator 122 of the bleed-on type. As depicted schematically in Figure 6, this type of regulator comprises a housing 124 enclosing a chamber 126 defined in part by the lower face of a movable wall 128 which is biassed downwardly, as depicted, by a compression spring 130 whose other end is retained by a disc 132 which is engaged by an adjustment screw 134 threadably received through the upper wall of the housing 124. The upper face of the wall 128, together with the housing 124, defines a chamber 136 which is vented by a vent port 138.

The movable wall 128 is comprised of a disc 140 and a flexible diaphragm 142 secured at the peripheral edge of the disc 140. The peripheral edge of the diaphragm 142 is secured to the housing in known manner. The lower face of the movable wall 128 engages the upper end of the stem of a poppet valve 144 which is slidably received through a stem guide in the lower wall of the housing 124 which is provided with a downwardly extending housing portion 146. The portion 146 is provided with a valve seat 148 co-operatively arranged for seating engagement by the poppet valve 144. A light compression spring 150 disposed between the housing portion 146 and the head of the poppet valve 144 serves to urge the valve 144 in a closing direction against the seat 148.

The housing portion 146 defines a fluid passageway 152 communicating between ports 154 and 156 as controlled by the poppet valve 144. The port 154 is arranged to be connected to a supply source of pressurised fluid (not shown) and the port 156 provides an outlet for pressure regulated fluid to which the supply conduit 108 of Figure 2 is coupled. A passageway 158 through the wall of the housing 124 provides communication between the chamber 126 and the passageway 152 downstream of the valve 144. As will be evident, regulated pressure at the port 156 results when the fluid supply pressure at the port 154 is manifest in the chamber 126 through the passageways 152 and 158, and on the movable wall 128 to raise it against the calibrated force of the spring 130 and permit the poppet valve 144 to approach the seat 148 and thereby maintain the pressure at its regulated figure. Regulated fluid pressure is desirable when the pressure of the supply source is greater than would be feasible for use by the control system.

In many cases it is desirable to provide a limitation of the working air temperature supplied to the compartment 10, and in particular to limit the temperature of the air at some distance upstream of the compartment, as in the supply duct, for example. To this end a fluid temperature transducer 160 is provided, mounted on the duct 12. As depicted schematically in Figure 7, the transducer 160 comprises a housing 162 having an upper portion defining a passageway 164 communicating between ports 166 and 168. Disposed in the passageway is a valve 170 shown here as a poppet valve arranged for co-operation with a valve seat 172 formed as a part of the housing 162 in the passageway 164. The stem of the valve 170 extends through the upper housing wall into the lower housing portion where the end of the stem is spaced from but adapted to be engaged by the centre of a bimetallic disc 174 which flexes convexly upwardly at its centre with increasing temperature of the working fluid to which it is exposed in the duct 12 of Figure 2. This device is shown and described in Application No. 21872/78 (Serial No. 1604543).

As the centre of the disc 174 engages the end of the stem of the valve 170 at the predetermined crack-point temperature of the working fluid, it lifts the valve 170 off the seat 172 against the light force of a compression spring 176 disposed between the head of the valve 170 and the housing wall above it. As the working fluid temperature increases above the crack-point, the valve 170 opens further with increased flexing of the disc, and control fluid flow between the ports 166 and 168. With still further increase of working fluid temperature, the valve 170 modulates open until, at the predetermined set-point for limitation of the temperature of the working fluid in the duct, the valve 170 is wide open.

As disclosed in Figure 2, the transducer 160 has its port 166 communicating with the chamber 24 of the valve control 20 via a bleed conduit 178, and its port 168 is vented to ambient. Thus, as the valve 170 of the transducer 160 modulates between the crack-point and set-point temperatures of the working fluid, the flow control valve 18 in the hot air supply duct 14 follows, and is modulated between open and fully closed positions.

In addition to the features enumerated above, the embodiment of Figure 2 features a mode selector 180 which is a two-position device adapted to select either a manual or an automatic mode of system operation. Referring to Figure 8, there is depicted schematically one form of a mode selector 180 having a housing 182 within which is disposed a rotatable cylindrical-segment selecting element 184, the lower face of which is provided with a recessed passageway 186 adapted to establish communication between ports 188 and 190 in the housing 182, when disposed in a first position, and between ports 190 and 192 when rotated to a second position. The rotatable element 184 is recessed on its upper face to receive a tang 194 of an operator member 196 inside the upper portion of the housing 182. An operator handle 198, having a stem extending through the upper wall of the housing 182 and secured to the member 196, rotates the element 184.

Referring to Figure 2, the port 188 of the mode selector 180 is coupled by a conduit 200 to the signal output port 84 of the second controller 36, to which is coupled the third supply conduit 114 through the orifice 120. A conduit 202 couples the port 190 of the mode selector 180 to the chamber 24 of the valve controller 20, and the port 192 is coupled to the conduit 102 by a conduit 204.

As mentioned, the selector 180 gives the system added flexibility by enabling the pilot to select either manual or automatic system operation. Turning the operator handle to one position couples the conduit 102, and hence the temperature selector 32, directly to the valve controller 20 via the conduit 204, port 192, recessed passageway 186, port 190, and conduit 202, whereby control of the mix air temperature may be directly controlled by the temperature selector. This feature provides manual override of the automatic mode in the event of failure of either of the controller means 34 or 36, or of the interconnecting conduits.

If the automatic mode is desired, the operator handle is turned to the other position, which closes off the signal bypass through the conduit 204 and couples the signal output port 84 of the second controller 36 to the valve control means via the conduit 200, port 188, recessed passageway 186, port 190, and conduit 202. It should be noted that a function of the second controller means 36 is to control the mixed air temperature to a maximum value. Hence during manual operation there is no limitation to the selected duct temperature other than that which is provided by the fluid temperature transducer means 160.

A wide latitude of selection is provided to the designer in adapting the system to a large variety of problems. For example, in one development design undertaken, a high degree of position control was achieved by the selection of the bellows area, type of halogenated hydrocarbon selected to fill the bellows, and calibration spring values of the temperature sensors of the first and second controller means 34 and 36 to give the temperature sensor of the first controller a gain, with respect to bias pressure, which was approximately fifty times that of the temperature sensor of the second controller. Thus, a 1°F signal to the temperature sensor of the first controller commands a 50°F set point change in the temperature sensor of the second controller means.

OPERATION OF THE SYSTEM OF FIGURES 1 AND 2

The automatic mode of operation of the two-controller system is based on the concept of total bleed. This is, the bleed of the pressure in the conduit 102 by the temperature selector 32, thus providing a first conditioned control signal, is usually steady, in the absence of any change of selector setting. Bleed at the controller 34 from the conduit 104, providing a second conditioned control signal, is also nominally steady but subject to modulation at the controller 34 by variations of cabin air temperature and subject to any changes made at the selector. The compression spring in the head of the controller 34 provides calibration adjustment means acting in aid of the head pressure and in opposition to the temperature sensor force. Finally, bleed at the controller 36 from the conduit 106 of Figure 1, or conduits 200 and 202 of Figure 2, is likewise nominally steady but subject to modulation at the controller 36 by variations of duct temperature and by variations of the pressure of the second conditioned control signal in the conduit 104. Likewise, the compression spring in the head of the controller 36 provides calibration adjustment means for that controller.

Increased bleed from the conduit 102 by selection of a lower cabin temperature causes a chain of increased bleeds with lower pressure in the conduit 104 and 106 (or 200, 202) to reduce the temperature quickly until equilibrium is reached. Higher cabin temperature selection results in decreased bleeds from the aforesaid conduits.

In the event of cabin temperature change

from any cause, the bleeds from the controllers 34 and 36 will increase or decrease with respective higher or lower temperatures sensed by the cabin temperature sensor means. A corresponding change of bleed from the controller 36 will occur with duct temperature change.

The excellent performance of a typical system in the automatic mode is indicated in the performance graphs shown in Figures 9 and 10. Both figures are curve plots of cabin temperature, duct temperature, and control valve position, respectively, against time in seconds. Figure 9 shows the time response of the system to a commanded increase in cabin temperature of approximately 15°F. As can be seen, the system responded in a fraction of a second and raised the cabin temperature into the desired range in about two minutes. The overshoot was a very nominal two degrees. Figure 10 shows the time response of the system to a commanded decrease in cabin temperature of about 15°F. In this particular case the flow available from the cooling air source was less than that from the heating air source, resulting in a somewhat slower response. It will be noted that the flow control valve moved immediately to the full cold closed position and remained in that position for nearly a full minute.

In the manual mode of operation, the performance of the temperature limiting transducer can be seen by referring to Figure 11 which is a curve plot of duct temperature, and of valve position, against time in seconds. The initial increase and dwell in valve position was caused by the input of the manual selector. As the duct temperature reached the limit, the actuator pressure in the control chamber of the valve control means was bled off such that the working fluid flow control valve modulated toward the closed position and maintained the duct temperature at the limit.

Turning now to the system depicted in Figure 3, there is illustrated an embodiment employing only one controller in a system for the control of the temperature of the ventilating air supply to an aircraft having an unpressurised cabin. A portion of the cabin 300 is shown supplied with ventilation air from a supply duct 302 which is coupled to a supply of hot engine bleed air by a duct 304 and a pair of ambient air supply ducts 306 and 308 within which are disposed normally-closed check valves 310 and 312, respectively. The duct 308 also has a fan 314 disposed therein.

A mixing valve 316, illustrated in schematic fashion, is disposed intermediate the hot air supply duct 304 and the supply duct 302 to inject the primary hot air from the duct 304 with the secondary ambient air from the duct 306 and directly into a mixing section 318 of the duct 302 for delivery to the cabin. The mixing valve 316 is a two-part assembly comprising a modulating and shut-off valve member 320 and an ejector bypass valve member 322.

The modulating and shut-off member 320 includes a duct section 324 whose inlet is coupled to the hot air duct 304 and whose outlet merges with the inlet duct section 326 of the ejector bypass member 322. The duct section 324 defines a passageway 328 having an end co-operating with a poppet valve 330 which is adapted to modulate or shutoff the hot fluid flow from the inlet duct section 326 into the valve member 322. The valve 330 has a stem 332 coupled to a movable wall 334.

The valve 316 further comprises a housing 336, to the interior of which is secured the peripheral edge of the movable wall 334 to define therewith a fluid pressure control chamber 338 having a control fluid pressure signal input port 340. The application of fluid pressure to the chamber 338, acting on the movable wall 334 against the closing force of a compression spring 342 causes the poppet valve 330 to uncover the passageway 328.

The inlet duct section 326 of the bypass valve member 322 communicates through a throttle orifice 344 with a first passageway leading to an ejector nozzle 346 which is arranged for aspirating a flow of secondary ambient air from the duct 306 by the flow of primary air through the nozzle into the duct section 318. A second, bypass, passageway leads from the exhaust of the throttling orifice 344 past a bypass valve 348 which is positioned by the pressure difference across the orifice 344 as manifested on a piston which is secured to the stem of the valve 348.

Additional structural details and operational features of a mixing valve of the type briefly shown and described here, are disclosed in Application No. 21871/78, (Serial No. 1604542).

Disposed in the upstream end of the supply duct 302 and in the immediately downstream end of the mixing section 318, is a fluid temperature transducer 160 of the type shown in Figure 7. Also disposed in the supply duct 302 is the temperature sensor 92 forming a part of the controller of the type depicted at 34 and 36 in Figures 1 and 2, and shown in Figure 5. In the cabin 300 is disposed a temperature selector 32 of the type shown in Figure 4. Also disposed in the cabin is an ON-OFF mode selector 180 of the type shown in Figure 8.

A supply of pressure regulated control fluid is furnished through a supply conduit 350 from the pressurised hot air duct 304 to the inlet port 154 of the pressure regulator 122 whose outlet port 156 is coupled by a conduit 352 to the port 192 of the mode selector 180. A supply conduit 354 has one

end coupled to the port 190 of the selector 180, and the other end joins with supply conduits 356 and 358 which supply pressure regulated control fluid to the orifices 116 and 120, respectively. The port 58 of the temperature selector 32 is coupled by the conduit 102 to the signal input port 100 of the controller 34—36 whose signal output port 84 is coupled by a conduit 106 to the port 340 of the valve member 320. As can be seen, the conduits 356 and 358 communicate through the orifices 116 and 120, respectively, with the conduits 102 and 106, respectively. The port 166 of the transducer 160 also communicates with the conduit 106.

OPERATION OF THE SYSTEM OF FIGURE 3.

As can be seen, whereas the system of Figures 1 and 2, employed two controllers 34 and 36 coupled in cascade between the temperature selector and the working fluid flow control valve, in Figure 3 there is only one controller 34—36 disclosed with its temperature sensor 92 arranged to sense the temperature of the fluid in the duct 302. It is apparent, of course, that in a proper case the temperature sensor could be disposed to sense the temperature of the fluid in the cabin 300, instead of in the duct. It will also be apparent that a second controller with a cabin temperature sensor could be easily added to the system of Figure 3 to provide complete "hands-off" control of cabin temperature for variations in heating load.

If it is desired merely to supply the cabin 300 with ambient air, the fan 314 is switched ON and the mode selector is turned to the OFF position, in which the control fluid supply at the port 192 is cut off by the blank wall portion of the rotatable element 184 (see Figure 8) and the pressures in all the conduits downstream of the conduit 354 are vented via port 190, recessed passageway 186 and the vent port 188 of the selector 180. Venting of the conduit 106 in this fashion results in venting the chamber 338 of the valve 320, whereupon the force of the spring 342 on the movable wall 344 operates to move the poppet valve 330 to close off the passageway 328 and shut off the flow of hot air into the duct 302.

If it is desired to add heat to the ambient air, the mode selector is turned to its ON position, either with the fan on or off. In the selector ON position, pressure regulated control fluid is supplied to the conduit 354 and all the downstream conduits, from the supply conduit 352 through the port 192, the rotatable element recessed passageway 186 and the port 190. The system then acts to add heat by controlling flow at the poppet valve 330 as a function of the fluid reference pressure supplied by the temperature selector 32 to the controller 34—36 which conditions that pressure signal as a function of the action by the duct temperature sensor 92 and supplies the conditioned signal to the control chamber 338 of the valve 320.

If the fan is ON in the heat-add mode, the ejector nozzle 346 merely acts to direct a portion of the hot air into the mixing section 318 with the bypass valve 348 providing a flow path for the balance of the hot air, since the check valve 310 is closed. If the fan is OFF, the check valve 312 is closed and ambient air is drawn into the conduit 306, past the open check valve 310 and aspirated into the mixing section 318 by the primary hot air from the ejector nozzle means 346. The function of the modulating and shutoff valve member 320 and the throttling orifice means 344 co-operatively with the nozzle means 346 and the bypass valve 348 to achieve flow characteristics is explained at length in the aforementioned patent application and need not be gone into here.

The systems of Figures 1, 2 and 3, as was said, are based on the concept of bleed off control fluid continuously available. Bleed is accomplished at the vent ports 60 and 82 respectively of the temperature selector 32 and the first and second controller 34 and 36. Preferably these ports bleed to ambient atmosphere as a convenient sink source of lower pressure than will obtain in the coupling conduits 102, 104 and 106 (or 200, 202 in the case of Figure 2). Preferably also, the port 138 of the pressure regulator 122 is also vented to ambient atmosphere. To this end it is usual practice to provide a common vent manifold for these vent ports to establish communication for them with ambient atmosphere.

WHAT WE CLAIM IS:—

1. Apparatus for producing at a signal output port a fluid pressure output signal which is dependent on a fluid pressure input signal and on a sensed temperature, comprising a metering valve, pressure responsive means arranged to exert on a movable valve member of the metering valve a force dependent on the fluid pressure input signal, but substantially independent of the fluid pressure output signal, temperature responsive means arranged to sense a fluid temperature and to exert on a movable valve member of the metering valve a force dependent on the sensed temperature, and fluid pressure supplying means supplying a restricted flow of fluid to the output port whence the metering valve bleeds fluid to vary the output signal.

2. Apparatus as claimed in Claim 1, in which the pressure responsive means comprises a movable wall bounding a chamber, to which the fluid pressure input signal is supplied.

3. Apparatus as claimed in Claim 1 or Claim 2, in which the force exerted by the

pressure responsive means acts in the sense to close the metering valve.

4. Apparatus as claimed in Claim 1 or Claim 2 or Claim 3, in which the force exerted by the temperature responsive means acts in the sense to open the metering valve.

5. Apparatus as claimed in any of the preceding claims, in which the forces exerted by the pressure responsive means and by the temperature responsive means act, in opposite directions, on the same movable valve member of the metering valve.

6. Apparatus as claimed in any of the preceding claims, which also includes biasing means arranged to bias a movable valve member of the metering valve in the sense to close the metering valve.

7. Apparatus as claimed in Claim 6, when appendant to Claim 2, in which the biasing means comprises a spring housed in the chamber bounded by the movable wall.

8. Apparatus as claimed in Claim 6 or Claim 7, which also includes means for adjusting the biasing force exerted by the biasing means.

9. Apparatus as claimed in any of the preceding claims, in which the fluid pressure supplying means comprises a conduit having an orifice to restrict the flow.

10. Apparatus as claimed in any of the preceding claims, in which the side of the metering valve remote from the fluid pressure supplying means is connected to ambient atmosphere.

11. Apparatus for producing a fluid pressure output signal which is dependent on a fluid pressure input signal and on a sensed temperature, the apparatus being substantially as herein described, with reference to Figure 5 of the accompanying drawings.

12. Apparatus for producing a fluid pressure output signal which is dependent on a fluid pressure input signal and on two sensed temperatures, the apparatus comprising first and second apparatus as claimed in any of Claims 1 to 10, the fluid pressure output signal of the first apparatus being connected as the fluid pressure input signal of the second apparatus, and the fluid pressure output signal of the second apparatus constituting the fluid pressure output signal of the entire apparatus.

13. A system for controlling the flow of ventilating air to a compartment, the system comprising a supply duct having a flow control valve, and apparatus as claimed in any of Claims 1 to 10 or 12, the temperature responsive means of the apparatus being positioned to sense the temperature of the ventilating air downstream of the flow control valve, and the system also including a fluid pressure responsive actuator connected to receive the fluid pressure output signal from the apparatus and to position the flow control valve in accordance with the output signal, and setting means arranged to provide a steady fluid pressure input signal to the apparatus.

14. A system as claimed in Claim 13 in which the, or one of the, temperature responsive means is positioned to sense the temperature of the air in the supply duct, downstream of the flow control valve.

15. A system as claimed in Claim 13 or Claim 14 in which the, or one of the, temperature responsive means is positioned to sense the temperature of the air in the compartment being ventilated.

16. A system as claimed in Claim 13 or Claim 14 or Claim 15, in which the setting means comprises a bleed valve which is adjustable to vary its resistance to fluid flow, and second fluid pressure supplying means connected to the bleed valve to pass through the bleed valve an approximately constant flow of fluid, the junction of the second fluid pressure supplying means and the bleed valve being connected to supply the fluid pressure input signal for the said apparatus.

17. A system as claimed in Claim 16, in which the second fluid pressure supplying means comprises a conduit having an orifice to restrict the flow.

18. A system as claimed in any of Claims 13 to 17, which also includes a mode selector valve connected between the fluid pressure output of the said apparatus and the fluid pressure responsive actuator, and also connected to receive the fluid pressure input signal from the setting means, the mode selector valve having a first position in which it supplies to the fluid pressure responsive actuator the fluid pressure output signal of the said apparatus, and a second position in which it supplies to the fluid pressure responsive actuator the fluid pressure signal produced by the setting means.

19. A system as claimed in any of Claims 13 to 18, which also includes a source of air at superatmospheric pressure, connected to supply air to the or each fluid pressure supplying means.

20. A system as claimed in any of Claims 13 to 19, which includes a pressure regulator connected to regulate the fluid pressure supplied to the or each fluid pressure supplying means.

21. A system as claimed in any of Claims 13 to 20, which also includes temperature limiting means comprising a normally-closed valve connected, when open, to provide a bleed path communicating with the fluid pressure responsive actuator, and temperature sensing means positioned in the flow of ventilating air between the flow control valve and the temperature responsive means of the said apparatus, the temperature sensing means being arranged, on sensing a ventilating air temperature above a threshold value, to open the normally-closed valve, and, with

further increases in sensed temperature, to increase the opening of the normally-closed valve.

22. A system for controlling the flow of ventilating air to a compartment, the system being substantially as herein described, with reference to Figure 1 or Figure 2 or Figure 3 of the accompanying drawings.

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Chartered Patent Agents,
Agents for the Applicants.

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1604541 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

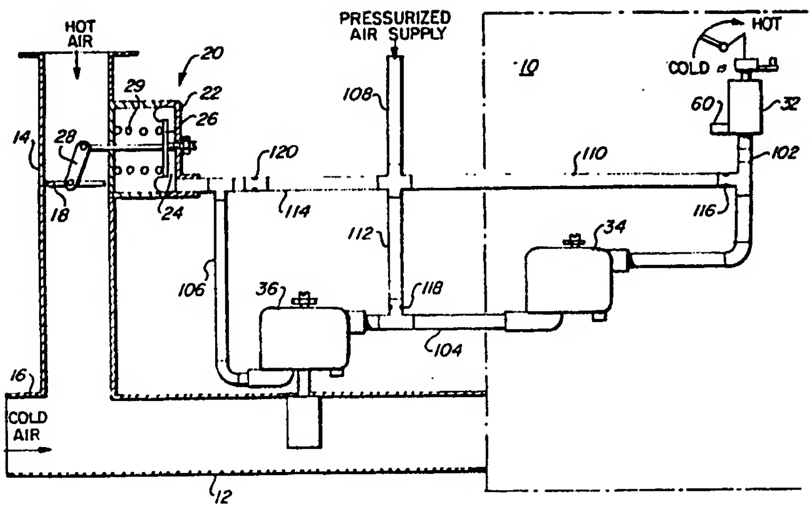

FIG-1

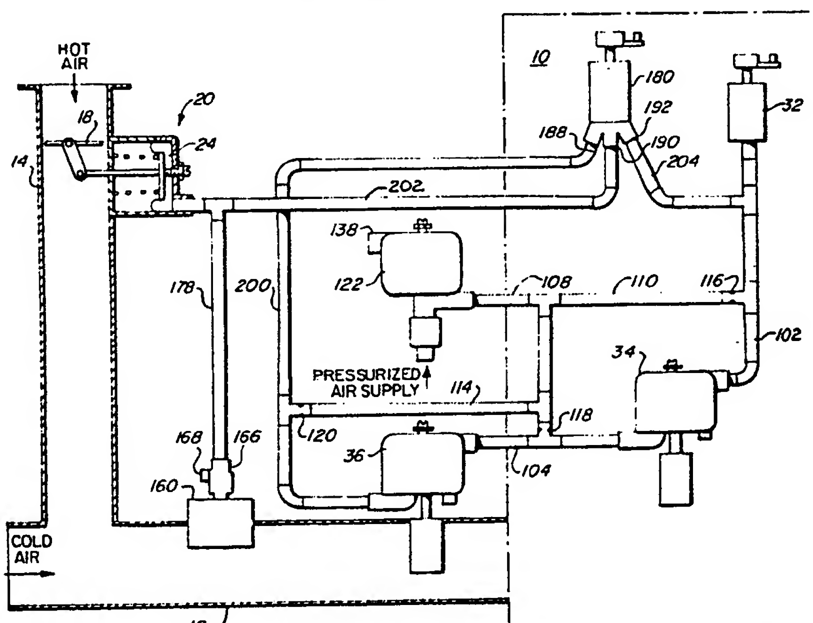

FIG-2

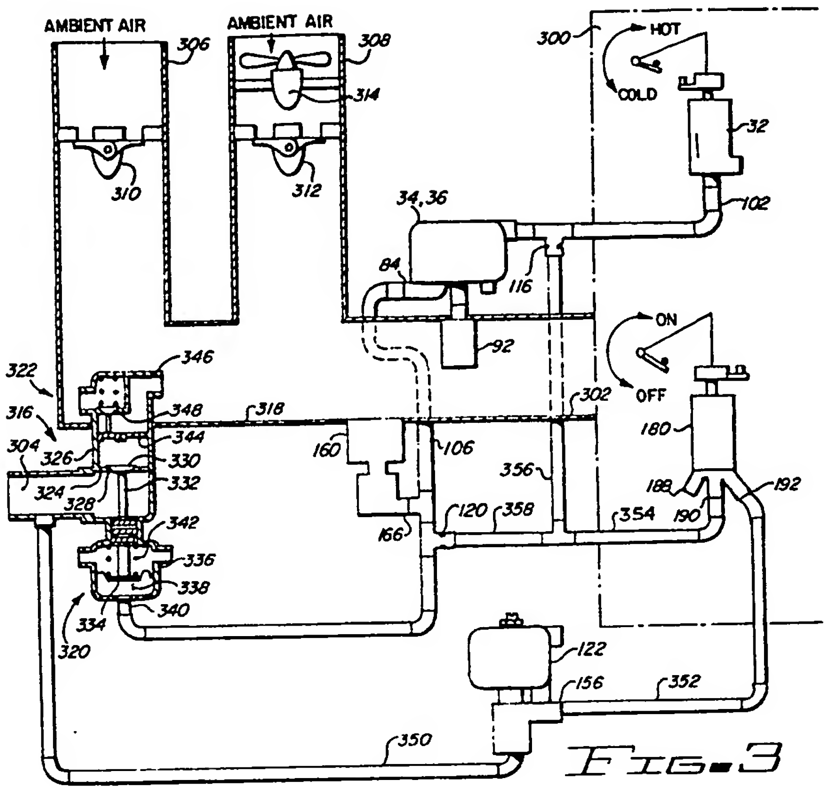
AMBIENT AIR
AMBIENT AIR
306
308
314
310
312
300
HOT
COLD
32
102
34,36
84
116
92
ON
OFF
322
346
316
348
318
302
180
304
326
344
330
160
106
356
324
332
328
342
120
358
354
188
190
192
166
336
338
340
334
320
122
156
352
350

FIG. 3

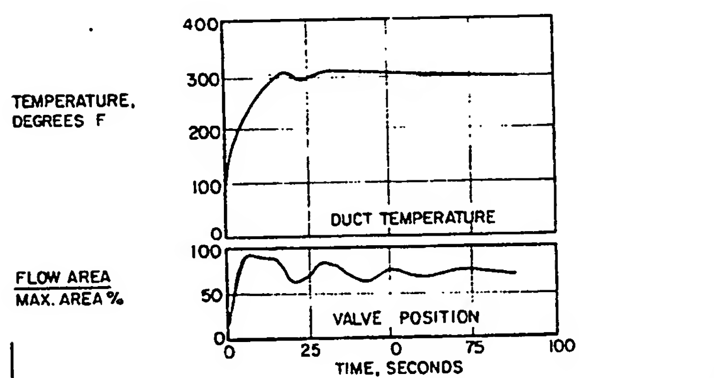
TEMPERATURE, DEGREES F
400
300
200
100
0
DUCT TEMPERATURE
FLOW AREA / MAX. AREA %
100
50
0
VALVE POSITION
0
25
0
75
100
TIME, SECONDS

FIG. 11

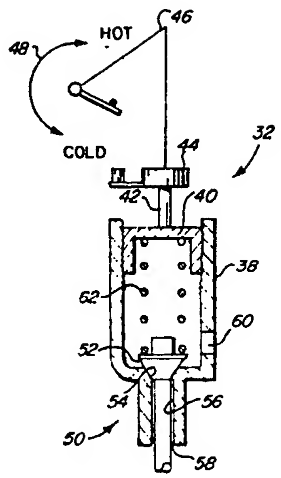

FIG-4

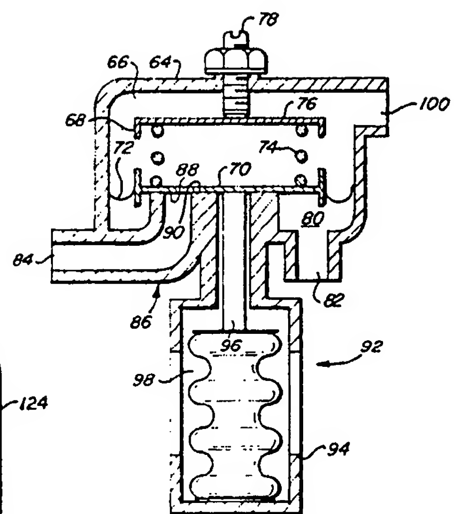

FIG-5

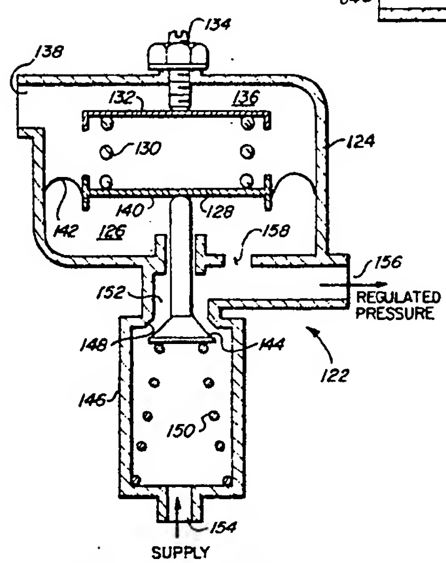

FIG-6

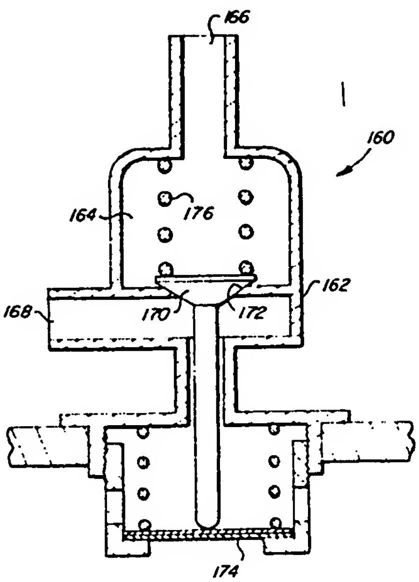
166
160
164
176
162
168
170
172
174

FIG-7

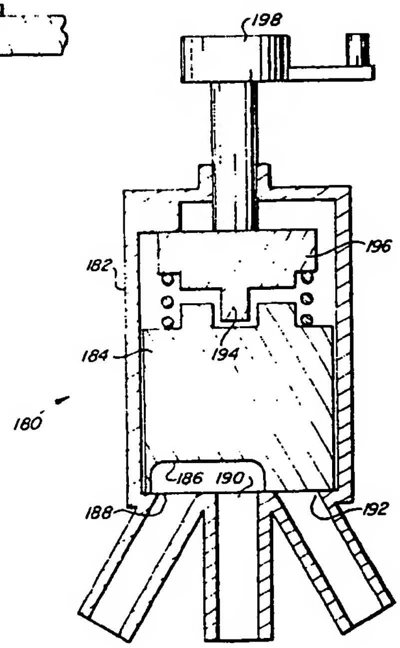
198
196
182
194
184
180
186
190
188
192

FIG-8

1604541 COMPLETE SPECIFICATION

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Sheet 5

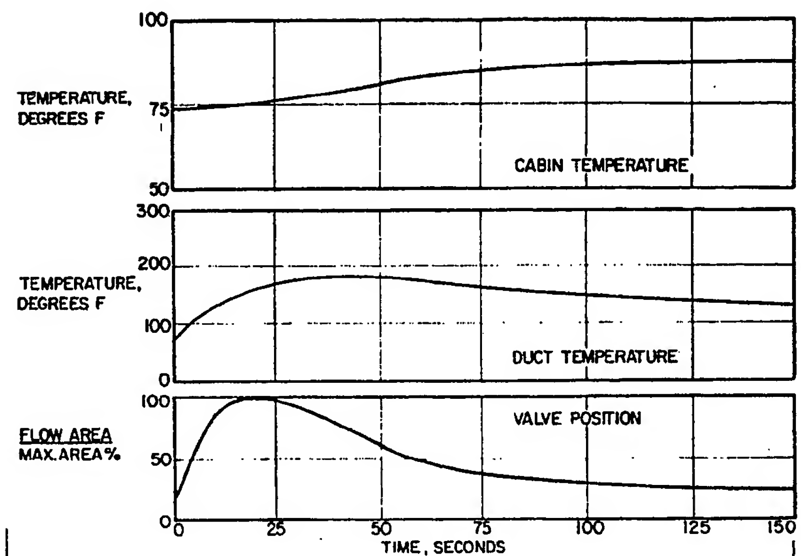

FIG. 9

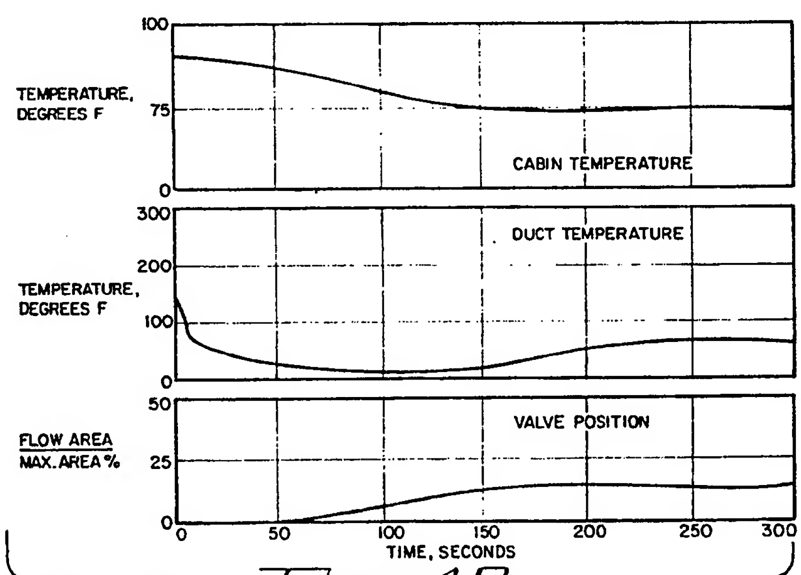

FIG. 10